Modeling and Experiments

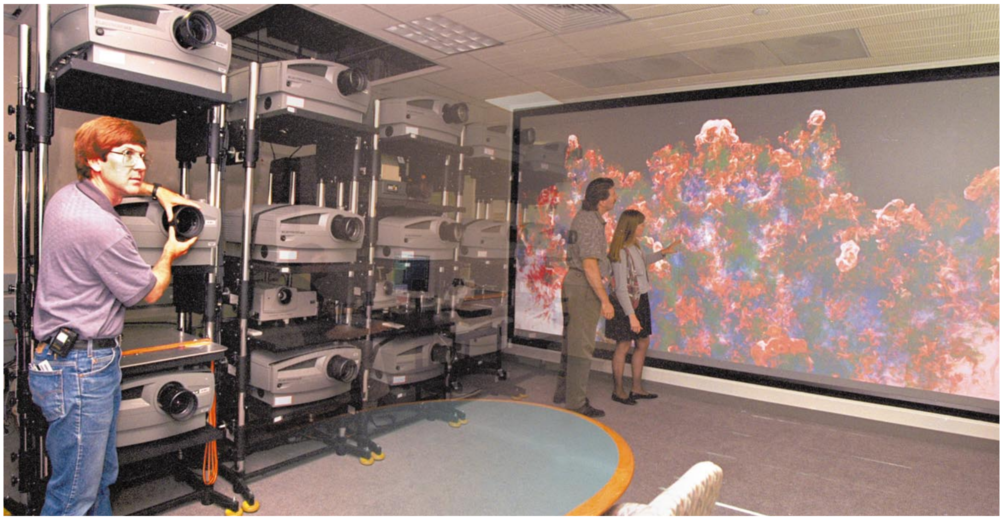
Decisions and actions about the stockpile must be grounded in experimental reality. In the past, that reality included nuclear testing. Now, we go about the business of ensuring stockpile performance using laboratory experiments and computer modeling to achieve a much more sophisticated understanding of underlying physics and engineering issues.

We are using the Omega laser at the University of Rochester to conduct high-energy-density experiments while NIF is being constructed. Omega is similar to Nova in its ability to deliver energy to a target.

Understanding Plutonium

We are making significant progress in understanding plutonium, which is an extremely complicated material. To study the subtleties of this metal, we have combined advances in theoretical modeling of plutonium with the use of research tools made available through Stockpile Stewardship Program investments. We need to understand aging in plutonium and the effect of aging-related changes on the performance of an imploding pit of a stockpiled weapon. Otherwise, we will not be able to accurately assess the lifetime of weapon pits and determine whether the nation must invest in new capabilities for plutonium operations.

One tool we use is subcritical testing at the Nevada Test Site. Livermore scientists are carrying out a series of experiments to investigate the properties of plutonium shocked and accelerated by high explosives. Matter can be ejected from the surface of materials that undergo shock. We are trying to characterize plutonium ejecta, which are thought to affect the performance of primaries in weapons. In 1999, we conducted three successful subcritical experiments: Clarinet in February and Oboe-1 and Oboe-2 in September and November.



During the calculation of a nuclear primary explosion, 6 million megabytes of data were written in a total of 50,000 graphics files. Analyzing the generated data from the Blue Pacific supercomputer requires powerful visualization tools. The extremely high resolution and superior image quality of Livermore's Assessment Theater provide weapon scientists with detailed views of the results of complex simulations.

Unlike the previous experiments, the Oboe tests were the first to be performed inside individual confinement vessels. As a result, personnel are now allowed to enter the underground test chamber—the zero room—to retrieve films and data after the test, once the chamber is determined to be free of contamination. The use of vessels for subcritical experiments will result in significant cost reduction and improved data return. In the past, each subcritical experiment took a minimum of one year to field and rendered unusable all diagnostic equipment in the zero room.

We also will be carrying out accelerated aging tests on specially prepared plutonium samples. They include a mixture of isotopes different from that used in weapons-grade plutonium, so we will be able to accelerate the rate of self-irradiation damage, which is a key factor in aging.

3D Simulation of a Nuclear Explosion

As Secretary Richardson announced in December 1999, the first-ever three-dimensional simulation of a nuclear weapon primary explosion was completed using the Blue Pacific supercomputer at Livermore. The simulation is a major milestone in the Stockpile Stewardship Program and an important step forward in the full-system modeling of weapon performance.

Three-dimensional simulation is critically important because phenomena during a nuclear explosion—such as high-explosive detonation, hydrodynamics, and radiation transport—are not symmetric in many cases because of aging and manufacturing variations. To accurately model the interaction of these complex phenomena demands unprecedented computational capability.

The computer model that was used employs tens of millions of zones—hundreds of times more than a comparable two-dimensional simulation. The simulation ran a total of 492 computer hours and used 640,000 megabytes of memory (in contrast to tens of megabytes of memory in a typical desktop computer).

The work was completed through an intense, sustained effort that involved weapons code developers and computer support personnel at Livermore and from IBM. It required innovative three-dimensional algorithms able to represent the relevant physical processes and run efficiently on the Blue Pacific machine's parallel architecture.

Nova Ceases Operation

In July 1999, operations ceased at Livermore's Nova laser facility in order to bring online the National Ignition Facility (NIF), which will be more than 60 times more powerful than Nova. High-energy lasers serve as experimental tools to generate data and validate simulation codes near—but not quite at—weapon-physics conditions. Until NIF operations begin, we are using the Omega laser at the University of Rochester to conduct high-energy-density experiments. Recent experiments at Omega have allowed a detailed comparison of two radiation transport models, with results that will be valuable for stockpile stewardship.